DGPS SIGNAL STRENGTH MEASUREMENTS AT A GWEN SITE

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Field strength measurements of a 300-kHz differential global positioning system signal transmitted at a Ground Wave Emergency Network site at Appleton, Washington were conducted. Data were acquired continually along five different routes and tagged with geographical position. Field strength along each individual route was plotted against distance from the transmitter and related to geological landmarks. Results were used as model inputs and to compare measured signal strengths with model predictions.

Key words: global positioning system (GPS); differential GPS (DGPS); signal strength measurements; Ground Wave Emergency Network (GWEN); propagation models

1. PURPOSE

The purpose of this study was to determine absolute differential global positioning system (DGPS) signal strengths at various distances from the Ground Wave Emergency Network (GWEN) site at Appleton, Washington. The transmitter, while owned and used by the U.S. Air Force Air Combat Command, has been temporarily reconfigured for DGPS transmissions on an experimental basis. Signal strength and background noise were measured along five different radial routes to compare the effects of different terrains. Results were used as model inputs and to compare measured signal strengths with model predictions.

2. STRATEGY

Measurements were conducted by driving five separate radial routes as shown in Figure 1. Data were only acquired during the daytime hours so that sky-wave effects were negligible. The first route started at Boise, Idaho (approximately 470 km southeast of the GWEN transmitter site) and followed Interstate 84 to Cascade Locks, Oregon (approximately 46 km west of the transmitter). All of the remaining routes started at Cascade Locks and ended at one of four locations: Bellingham, Washington; Medford, Oregon; Spokane, Washington; and Burley, Idaho (via Boise, Idaho). The route to Bellingham, Washington followed Interstate 84 east to Biggs, Oregon; Highway 97 north to Toppenish, Washington; Interstate 82 north to Ellensburg, Washington; Interstate 90 northwest to Seattle, Washington; and Interstate 5 north to Bellingham, Washington (approximately 330 km north of the GWEN transmitter site). The route to Medford, Oregon followed Interstate 84 west to Portland, Oregon, and Interstate 5 south to Medford, Oregon (approximately 400 km southwest of

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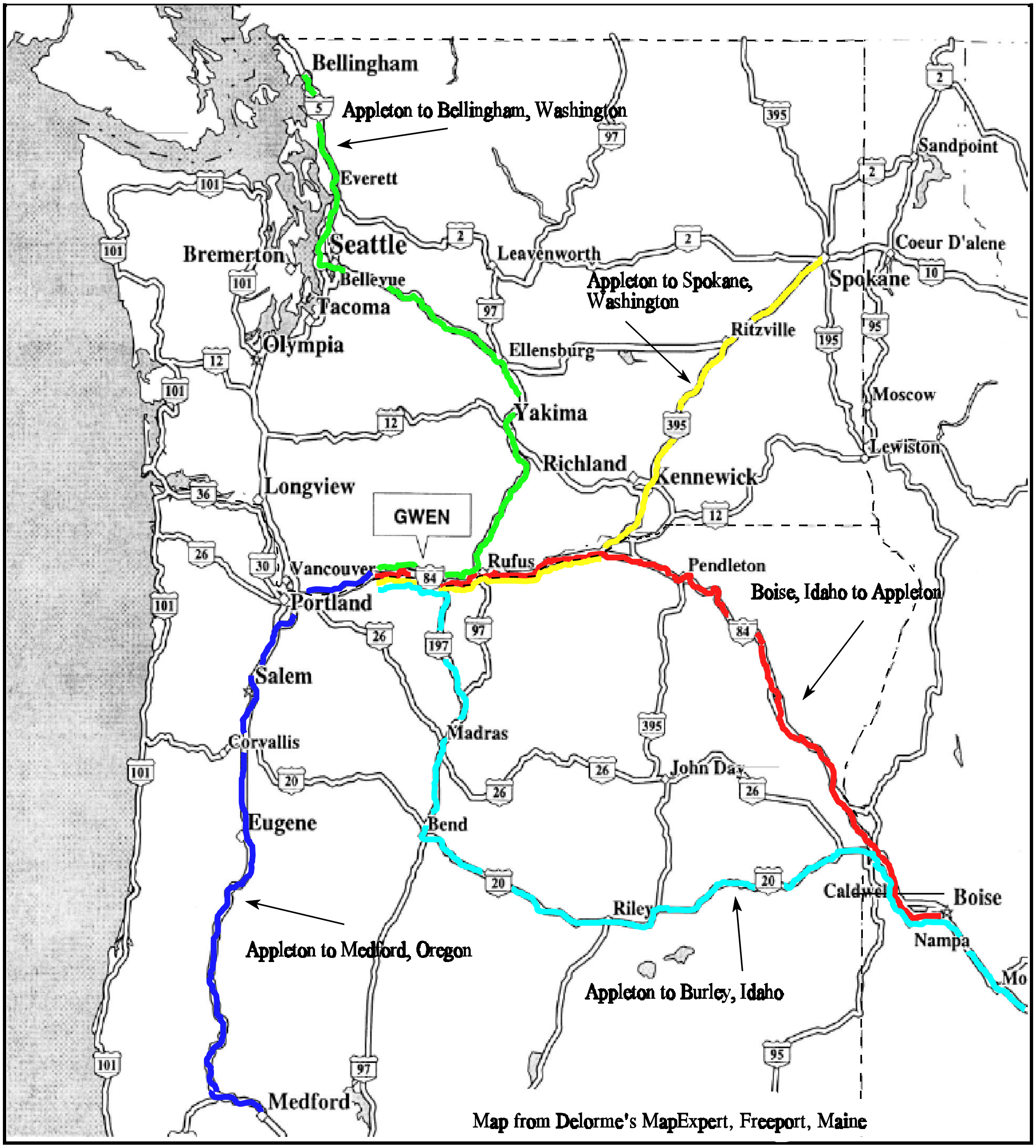

Figure 1. Measurement routes (in color) for DGPS signal strength (red) Boise, Idaho to the GWEN transmitter, (yellow) GWEN transmitter to Spokane, Washington, (green) GWEN transmitter to Bellingham, Washington, (dark blue) GWEN transmitter to Medford, Oregon, (light blue) GWEN transmitter to Burley, Idaho.

the GWEN transmitter site). The route to Spokane, Washington followed Interstate 84 east to Hermiston, Oregon; Interstate 82 to Kennewick, Washington; and Highway 395 northeast to Spokane, Washington (approximately 350 km northeast of the GWEN transmitter site). The route to Burley, Idaho followed Interstate 84 east to The Dalles, Oregon; Highway 197 south to Bend, Oregon; Highway 20 east to Ontario, Oregon; and Interstate 84 through Boise, Idaho to Burley, Idaho (approximately 700 km southeast of the GWEN transmitter site).

3. MEASUREMENT SYSTEM

The measurement system (Figure 2) consists of a receiving antenna, low-pass filter, high-pass filter, amplifier, spectrum analyzer, global positioning system (GPS)/dead-reckoning (DR) receiver, and a computer. The low-pass filter attenuates signals at frequencies above 400 kHz, particularly the AM broadcast signals. The high-pass filter attenuates signals at frequencies below 285 kHz. The computer is used to control the spectrum analyzer, download raw data, gather GPS information, and perform various computations. The overall gain of the system between the output of the antenna and the measured output of the spectrum analyzer is 22 dB. The noise figure of the system is 10 dB, resulting in a sensitivity of 1 dBµV/m in a bandwidth of 300 Hz. The GPS receiver has a dead-reckoning system so that, if satellite lock is lost, the proper coordinate information is maintained.

4. TRANSMITTER

The antenna at the Appleton GWEN site is 91.1 m (299 ft) tall supported by 15 guy wires. The cross section is a triangle that is 0.609 m (2 ft) long on each side. It has 12 top-loading elements. A radial ground plane extending from the base of the tower contains approximately 100 copper wires, each 100 m (330 ft) long, and buried 30 cm underground [1]. The tuning coils were modified for a 300-kHz DGPS transmission and the power into the antenna was set at 1 kW. Based on theoretical considerations, the efficiency is expected to be 50%, giving a total radiated power of 500 W. The predicted directive gain for the ground wave (in the horizontal direction) is approximately 6 dB. Therefore, the expected field strength at 10 km is approximately 91 dBµV/m (see Appendix A).

5. MEASUREMENT PROCEDURE

A computer controlled the acquisition of data using GPIB and RS232 commands sent to the spectrum analyzer and GPS receiver, respectively. Data also were downloaded via GPIB and RS232. Both noise and DGPS signal strength data were acquired.

At the beginning of data acquisition and at approximately 20-min intervals, the spectrum between 285 kHz and 325 kHz was scanned for a frequency (f_{min}) where the noise was at a minimum. Prior to acquiring data on the DGPS signal, the noise power was measured at f_{min} (see Table 1). The noise power was measured to determine if the signal could be detected against the noise background. A single sweep was performed, after which, the mean, the standard deviation, and the peak noise power

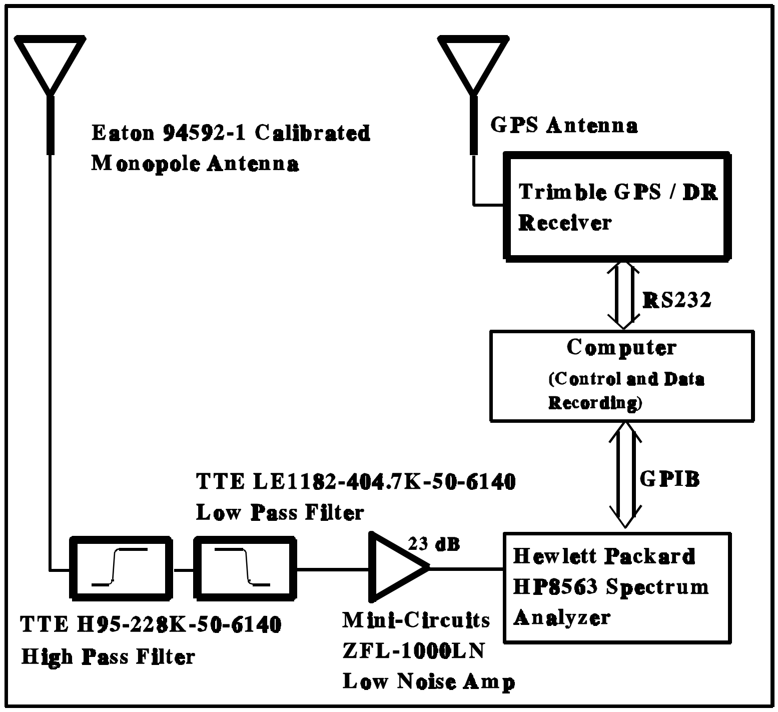

Figure 2. Block diagram of the measurement system.

were determined from 601 data points evenly spaced across the sweep. In addition, 50 samples evenly spaced across the 601 data points of the sweep were stored in the data file.

The DGPS signal strength was measured by performing 50 consecutive sweeps of a 500-Hz span. (see Table 1). After each sweep, the signal power at the DGPS center frequency was determined and recorded in the data file. Based on the antenna-correction factor and the known frequency, the signal field strength was calculated as described in Appendix B. With each sweep, a data string from the GPS was downloaded and placed in the file to mark the location of the acquisition. Each of the four parameters (frequency, power, field strength, and GPS coordinate string) was recorded for each of the 50 sweeps.

Two calibration procedures were conducted. The first procedure, performed immediately before measurements, was used to determine the total gain between the output of the antenna and the measured power determined by the spectrum analyzer. This gain was subtracted from the measured power to determine the power at the output of the antenna. The procedure amounted to putting a signal of known power into the cable which was normally connected to the antenna, and then measuring the power on the spectrum analyzer. The difference between the known power and the measured power is the gain of the system, which in this case is approximately 22 dB.

The second calibration procedure was used to determine any differences in antenna characteristics between those measured in a laboratory (during which the antenna-correction factor was determined)

Table 1. Spectrum Analyzer Settings

Parameters	Low Noise Scan	Signal Strength	Received Noise
Detection Mode	Normal	Normal	Sample
Resolution Bandwidth	300 Hz	300 Hz	300 Hz
Video Bandwidth	300 Hz	10 Hz	1 MHz
Span	40 kHz	500 Hz	zero
Reference Level	-30 dBm	-10 dBm	-40dBm
Attenuation	0 dB	0 dB	0 dB
Sweep Mode	10 Sweeps	Single	Single
Video Averaging	On	Off	Off
Sweep Time	2.0 s	5.0 s	6.0 s
Frequency	285-325 kHz	Center Frequency of Beacon	Quiet area between 285-325 kHz
Data Acquired	Determine quiet region of spectrum	Power at Center Frequency	601 data points

and the characteristics of the antenna when placed on the measurement van. First, the antenna was placed at the center of a 1.3-m round backplane which, in turn, was mounted on a tripod approximately one m above ground. This backplane configuration was used to simulate the measurement conditions in the laboratory. The power of a known transmitted signal (such as a DGPS signal) was measured. Then, the antenna was mounted on the measurement van and the power of the same signal was measured at eight different azimuth orientations of the van (approximately 45° apart). Results showed no significant difference between the two different antenna mounts and among the eight different azimuth orientations.

In addition to the aforementioned calibrations, the system was checked on successive days by placing the measurement van in the same physical location and measuring the DGPS signal. The purpose of this was to quickly determine if any changes had occurred in the system from one day to the next. Less than 1 dB variation was noted during the course of the measurements.